

France (80 pages in length) is particularly interesting. And the chapter relating to Britain gives a general view of all the principal works which have been executed here, docks, piers, lighthouses, gates, bridges, (including some valuable specifications), and the model prison, with details of fittings. 160 pages are devoted to the treatise on geometry, and 80 to mechanics. The division appropriated to roofs embraces a large number of examples, and the chapter on stone bridges may be studied with great advantage.

The concluding chapter, 60 pages in length, treats of the principles of proportion, and will come under our especial notice hereafter, with other divisions of the work already alluded to.

In the meantime we give some specimens of the engravings, by which this work is profusely illustrated.\* Our selections all relate to the city of York. Bootham Bar is on the north-west side of the city; Monk Bar forms the entrance from the Scarborough road; and Micklegate Bar the entrance from London. The lower part of Monk Bar is of early date; the upper part belongs to the time of Edward III.

The Ouse bridge was erected in the reign of Queen Elizabeth, and was taken down a few years ago.

## THE LAWS OF SOUND WITH REFERENCE TO BUILDINGS.

ROYAL INSTITUTE OF ARCHITECTS.

A MEETING of the Institute was held on the 8th instant. Mr. S. Angell, V.P., in the chair. Mr. Carter exhibited a nice drawing of the interior of the church of St. Jacques, at Liege, as recently restored. Amongst the donations was a curious work on the Five orders, by Hans Bloem, published in Amsterdam in 1596, and which was presented by an anonymous author, with a request that it might be acknowledged in *THE BUILDER*. It was found amongst some unnoted lumber in a house formerly occupied by Evelyn, and, as the donor thought, probably belonged to him.

Mr. Scott Russell then resumed his paper on the interior forms of buildings, with reference to the laws of sound, and after briefly recapitulating his former discourse,† said, he thought it necessary to allude to the two letters which appeared in *THE BUILDER* of Saturday last. The first he would speak of, signed M. C. (p. 115, ante), evidently by one who was well acquainted with the circumstances, shewed that he was wrong in stating that Sir Humphrey Davy was concerned in the erection of the theatre of the Royal Institution, and that the late Mr. George Saunders deserved part of the credit of its success.‡ The other letter (p. 109) referred to the *isacoustic* curve, described by him at a previous meeting, and maintained that others had previously discovered it. All he could say was, that he had discovered it for himself, and that it was an instance of a well-known fact, that different minds often light on the same truth. He had no wish to arrogate any credit to himself, and he was glad to find his own views confirmed by others. Relative to spontaneous oscillation, of which he had spoken before, and the necessity of attending to proportion in the shape of buildings, he would mention, that since meeting them, he had visited a church which had the reputation of being one of the worst buildings for sound ever erected, and that he had found it bear out his views completely. We must confess, however, without wishing to throw any discredit on the statement of Mr. Russell, that the reasons given did not account to us with certainty for the result.

The third principle he had to treat of was this,—that the angle of reflection was the

same as the angle of incidence. This, although generally admitted, he considered only partly true. He had discovered, in his investigation of water waves, that this did not hold good when the angle was less than forty-five degrees, and he had every reason to believe, both from analogy and experiments, that it was the same with sound-waves. Reflected sound was the cause of much annoyance; reflection from the roof was the worst sort of reflection, and the most difficult to be overcome. Reflection had the effect of conveying a repetition of a sound to the ears of the auditors after the original sound had reached them, and so of producing confusion. The great point was to get rid of all reflected rays; the sound should be heard but once. In some rooms too, the thousand small sounds produced by a large crowd, such even as moving the feet, were taken up by the walls and ceiling and handed about, in addition to the voice of the speaker. A flat ceiling increased this disadvantage. In one of the worst rooms of this description he had ever met with (a parallelogram with the platform for speakers in the middle of the longest side), great improvement had been effected by moving the speaker into the corner.

The modification of the previously mentioned maxim, that the angle of incidence is equal to the angle of reflection, he would consider as a fourth principle. The maxim was true only so long as the angle of incidence was more than forty-five degrees; if less, there was no reflection, but the sound was gathered up, and travelled along the surface. He considered this an extraordinary fact, deserving attentive examination: it would explain the phenomenon of the whispering gallery in St. Paul's, which, on the reflective theory, was quite incomprehensible. It explained why the Arab hears very distant sounds by placing his ear near the ground. It was a vulgar notion to consider that the ground was the medium of communication,—it was the air immediately on the surface of the ground, not the ground itself.

The fact he had pointed out shewed the means of preventing reflection: it was only necessary to arrange the flat surfaces, so that sound waves would not impinge at an angle so large as 45°, and there would be no reflected sound. The old architects in our Gothic cathedrals had got rid of reflection. Our Italian Opera House, in the Haymarket, was admitted to be an admirable house for sound: the arrangement of the boxes was precisely the best sort of arrangement for preventing reflection. In Dr. Hook's church at Leeds, the speaker was singularly well heard; and in this church, he said, were combined all that he had spoken of as being likely to produce a good result: the roof was especially well-calculated to prevent reflection. He did not pretend to dogmatise, the subject was too obscure for that; he wished all he said to be regarded as merely suggestive, and he would conclude by deducing the following maxims:—

In a large room, nearly square, the best place to speak from is near one corner, with the voice directed diagonally to the opposite corner.

In all rooms of common forms, the lowest pitch of voice that will reach across the room will be most audible.

In all rooms of common forms, it is better to speak along the length of the room than across it; and a low roof will, *ceteris paribus*, convey the sound better than a high one. It is better generally to speak from pretty near a wall or pillar, than far away from it. It is desirable that the speaker should speak in the key-note of the room, and evenly, but not loud.

It is desirable that a rectangular room, or suite of rooms, should have their proportions multiples of the simple numbers 1, 2, 3, and 5, otherwise it will be difficult to give the noise equally. It is desirable, also, that the speaker be either at a corner, or at some simple proportion of the length,  $\frac{1}{4}$ ,  $\frac{1}{2}$ ,  $\frac{3}{4}$ , from the side, or corner, of the room.

In a room about to be built, equal seeing and hearing may be obtained by ranging the seats in the acoustic curve.

All surfaces at right angles to the direction of the sound should be avoided as far as possible; and angles of less than 45° with it substituted. If surfaces must be at right angles to the sound, they should be as distant as possible.

In a very large building, escape of the sound, even from the building, should be, if possible, provided by transversal wings.

In every case the separation of the wall surface into small receptacles, like the private boxes of a theatre, the recesses of a library, or the side chapels of a Gothic cathedral, is favourable to distinct hearing.

It is the belief of the writer, that a room formed on these principles might contain twelve to twenty thousand persons, all hearing perfectly a single human voice.

The chairman having invited discussion, Mr. Donaldson said,—“buildings in respect of sound were of two sorts, those wherein the speaker occupied one fixed position, as a church, and those wherein the speakers occupied a variety of different positions, as in the Houses of Parliament. For his own part he did not see any great merit in the construction of a theatre like that of the Royal Institution, which was small, and where the voice always proceeded from one place. He should have been glad if Mr. Russell had investigated such a room as Exeter Hall, which was admitted to be one of the worst rooms in London for sound. The practical application of the science of acoustics was unquestionably very difficult, and what answered in one place did not in another. As to the partitions in the boxes of our Opera House rendering it good for hearing, there were many theatres similarly divided and cut up, wherein nothing could be heard; the San Carlos, at Naples, was an instance: and as related to preventing reflection from a roof by projections, the ceiling of our Opera House was perfectly smooth. The church Mr. Russell had described as bad for hearing in, agreed precisely with others he knew of, where the preacher could be heard well; and only the day before he had been in a church (West Ham) containing all the irregularities pointed out, as likely to produce a bad church for sound, and yet there, with piers interposing between himself and the speaker, he had heard very well. He mentioned these points simply to shew the difficulties of the subject.

Mr. Russell said, as to Exeter Hall, he had before pointed out that it was necessary, in order to ensure hearing in so large a room, that the length, breadth, and height, should be in harmonious proportion, which was apparently not the case there; moreover, there was a chamber branching out from it at right angles, which was always detrimental to sound, and the flatness of the ceiling and walls further conduced to make it a bad hearing room. He was ready to admit, however, that he was far from considering himself a sound doctor; still he had never found a room which controverted his views.

Mr. Bromet instanced Horsham church in Sussex, as being remarkably good for hearing in.

Mr. G. Foggo thought it desirable to mention that the Hall of Commerce, in Threadneedle-street, was very good for music, but very bad for speaking in. Mr. Harper once trying it with a musical cane he had with him, found the reflection gave the octave of his original note.

Mr. Russell thought that room might be good for music, because it was well proportioned, and bad for speaking because it had a voice of its own, and speakers had not found out the keynote. If a man had to speak there constantly, he would soon find this out, and might then voice it with considerably less effort.

The conversation turning on the transmission of sound, Mr. Alexander referred to the occurrence of sounds in his and other houses in Bedford-square, the origin of which had baffled inquiry. Mr. Papworth corroborated the statement, and attributed the sounds to the bad construction of the houses, which led to unequal settlements, and consequent strains on the timber.

Mr. Poynter said, that at a parsonage-house in the country known to him, a knocking which was heard at certain times, and could not be explained, and had obtained for the house the reputation of being haunted, was found to be caused by the baker at the opposite end of the village chopping his wood. The sound, it was thought, was reproduced in an old well opposite the parsonage. Mr. J. A. Pictou, of Liverpool, instanced a case where similar sounds, heard in a house, were found to proceed from a steam-engine at a very considerable distance, and not audible elsewhere.

\* See page 129.

† See p. 62, ante.

‡ Doubt was expressed on this point by some of the members. All Mr. Webster's papers are in the possession of the Institute, including the minutes of council, during the erection of the theatre, and will probably enable us to set this question at rest when we have time to look through them. It affords an instance of the rapidity with which Time obscures facts.